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OF STATE HIGHWAY AND
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AASHTO

⌘ HISTORIC BRIDGE ⌘ PRESERVATION GUIDE

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SECTION 1: INTRODUCTION

1.1—BACKGROUND

The provisions of this *Historic Bridge Preservation Guide* are intended for the preservation and rehabilitation of both fixed and movable historic highway bridges. Mechanical, electrical, and special vehicular and pedestrian safety aspects of movable bridges, however, are beyond the scope of this Guide.

This Guide is intended to be used in conjunction with the *AASHTO LRFD Bridge Design Specifications* (AASHTO LRFD), and may be used with the *AASHTO Standard Specifications for Highway Bridges* when consistent with state requirements.

Historic bridge preservation and rehabilitation utilizes a unique and diverse set of skills and knowledge, and sometimes involves approaches to projects that are different than those used in ordinary bridge projects. This Guide addresses the elements of design for successful historic bridge preservation and rehabilitation projects.

1.2—DEFINITIONS

Accessibility—Accommodations to enable those with disabilities to use a facility, in compliance with the Americans with Disabilities Act (ADA), United States Access Board Standards (ABA), and state requirements.

All Possible Planning—All reasonable measures identified in the Section 4(f) evaluation to minimize harm or mitigate for adverse effects.

Consulting Parties—Parties to consultation under Section 106, i.e. SHPO/THPO, representatives of local government, applicants for federal funds or permits, etc., and others upon request.

De Minimis Impact—No adverse effect on a resource protected under Section 4(f) of the Department of Transportation Act.

Feasible—An alternative is feasible if it can be constructed as a matter of sound engineering.

FHWA—Federal Highway Administration of the United States Department of Transportation.

Historic Preservation—Preservation focused on maintaining historic significance and integrity while limiting replacement and construction of new material.

Impressed-Current Cathodic Protection (ICCP)—Method of protecting steel reinforcement in chloride contaminated concrete by forcing a small direct current to flow between the steel reinforcement and a permanent anode applied to the concrete surface, for a period of decades.

Intended Level of Service—The degree of structural capacity and functionality a preservation or rehabilitation project is designed to provide. The intended level of service should be consistent with actual use of the structure and functional category of the roadway and pedestrian path.

Internal Redundancy—The redundancy resulting from having multiple components within a larger member.

C1.1

This commentary is included to provide additional information to clarify and explain the technical basis for the specifications provided in this Guide. This Guide is for the design of bridge preservation and rehabilitation projects for existing bridges, particularly those of historic significance.

The term “may” indicates a criterion that is usable, but other local and suitably documented, verified, and approved criteria can also be used.

The term “recommended” is used to provide guidance based on past experiences.

When this Guide makes reference to a Section number or Article number, these references are to Section and Article numbers of this Guide, unless noted otherwise.

Least Overall Harm—The alternative that causes the least overall harm is determined based on consideration of the factors listed in 23 CFR§774.3(c), i.e.:

- Ability to mitigate adverse effects;
- Relative severity of remaining harm after mitigation;
- Relative significance of the historic resource;
- Views of the official(s) with jurisdiction over the historic resource;
- Degree to which each alternative meets the purpose and need of the project;
- Magnitude of adverse impacts to unprotected resources after reasonable mitigation; and
- Substantial cost differences among alternatives.

Load Rating—An analysis of a bridge’s capacity to support live loads; the basis for load posting.

Official(s) with Jurisdiction—Under Section 4(f), the SHPO/THPO, the Advisory Council on Historic Preservation (for Section 106 properties), and the National Park Service (for National Historic Landmarks).

Preservation—Preventing or delaying deterioration and restoring function to maintain the bridge in service.

Prudent—An alternative is prudent if it meets the definition given in 23 CFR§774.17, i.e., it is reasonable to proceed based on an assessment of:

- How well project purpose and need are satisfied;
- How well safety or operational problems are avoided;
- Severity of social, economic, or environmental impacts; and
- Severity of impacts to environmental resources.

SHPO—State Historic Preservation Officer.

THPO—Tribal Historic Preservation Officer.

1.3—PRESERVATION PHILOSOPHY

1.3.1—Historic Preservation Challenges

When performing work that could adversely affect historic bridges, several unique challenges must be addressed for the work to be successful. These challenges are not encountered in new bridge design.

- Achieving an appropriate balance between cultural/historic values and functional/safety characteristics.
- Design codes have changed since the bridge was originally designed, as have some material properties and detailing practices, making it challenging to repurpose a bridge into current standards.
- Historic preservation laws effectively create an additional permitting requirement with significant impacts to the types of work that can be performed, acceptable means and methods for performing the work, and project development schedules.

C1.3.1

The design of historic bridge preservation projects is a unique type of specialty engineering that draws from diverse bodies of knowledge and skill sets.

It should be noted that effective communication between the owner and the SHPO/THPO is critical.

1.3.2—Historic Preservation Laws

Historic bridges and structures adversely affected by an FHWA approved transportation project are protected by Section 4(f) of the Department of Transportation Act, with the following exceptions:

- Projects constructed solely using state, local, or private funds and not requiring FHWA approval.
- Structures on the Interstate freeway system unless previously identified by FHWA and state transportation departments on the basis of national or exceptional historic significance.
- Historic bridges or structures adjacent to an FHWA approved project, with no constructive use.
- Certain post-1945 steel or concrete bridges and culverts identified by FHWA and state transportation departments.
- Projects where Section 106 consultation results in a finding of “no adverse effect.”
- Projects under a Section 106 programmatic agreement.
- Railroad structures except in cases of abandonment.

Otherwise, historic bridges and structures affected by federal undertakings (i.e. any project using federal funds or requiring federal approval or permit, or affected by state or local regulations delegated or approved by a federal agency) are protected by Section 106 of the Historic Preservation Act of 1966.

Both regulations require consultation with the SHPO/THPO and other stakeholders to determine National Register of Historic Places eligibility and to determine whether an activity constitutes an “effect.”

If consultation determines that there is not an “adverse effect” one of the following will occur:

- Under Section 4(f) FHWA issues a de minimis impact determination with SHPO/THPO concurrence.
- Under Section 106 the federal agency issues a finding of no adverse effect.

C1.3.2

This description is a brief synopsis of the Section 4(f) and Section 106 laws; for more detailed information see *Federal Highway Administration (FHWA) Section 4(f) Tutorial* available on the FHWA website, the original statutes *Public Law 89-670 Department of Transportation Act*, and *Public Law 102-575 National Historic Preservation Act*, and the implementing regulations *23 CFR§774—Parks, Recreation Areas, Wildlife and Waterfowl Refuges, and Historic Sites (Section 4(f))* and *36 CFR§800—Protection of Historic Properties*.

In some cases, state laws also protect historic bridges and structures.

Under Section 4(f) and Section 106, a bridge or structure is historic if it is listed in or eligible to be listed in the National Register of Historic Places.

For specific cases, seek more detailed information from the applicable agency historians.

For more information on the exception for certain post-1945 steel bridges and culverts, see https://www.environment.fhwa.dot.gov/env_topics/historic_pres/roads.aspx.

Under Section 4(f) these other stakeholders include the Advisory Council on Historic Preservation for Section 106 properties and the National Park Service for National Historic Landmarks. Under Section 106 these other stakeholders are known as consulting parties and include representatives of local government, applicants for federal funds or permits, etc., and others upon request.

Section 4(f) resources may include parks, recreational areas, wildlife or waterfowl refuges, and other historic resources including archaeological sites, and as a result the selection of the alternative causing the “least overall harm to the Section 4(f) resource” must consider all applicable Section 4(f) resources.

If consultation determines that there is an “adverse effect” one of the following will occur:

- Under Section 4(f) FHWA coordinates with the Department of Interior and prepares an individual Section 4(f) evaluation that issues findings that (1) there is no feasible and prudent alternative to avoid using the Section 4(f) property and (2) that all possible planning was performed to minimize harm to the 4(f) property, and selects the alternative that causes the least overall harm to the Section 4(f) resource.
- Under Section 106 the federal agency issues a finding of effect, triggering further consultation, with the consulting parties and the Advisory Council on Historic Preservation, to resolve the adverse effect. If further consultation fails, consultation is terminated and a memorandum of agreement is produced documenting the results. In some cases, when consultation is terminated the project may proceed without agreement.

1.3.3—Historic Significance

Bridges with historic significance are those listed in or eligible for listing in the National Register of Historic Places. Bridges can be identified as historic on a local, state, or national level. Typically, bridges are considered historically significant due to their engineering or architectural design, or due to their connection with a larger trend in history. Less commonly, bridges may be significant due to their association with a famous person or as a part of a historic district, or when viewed in a larger multistate context.

In addition to having historic significance, historic resources must have integrity of their character-defining features in order to be eligible for the National Register. Character-defining features may include decorative features, structure type, railing design, location, construction method, or association.

C1.3.3

Most states have completed historic bridge inventories that can be used to identify the significant bridges constructed prior to 1945. In recent years, some states have revisited these lists and included more recent structures and trends. The use of these inventories is extremely valuable as a planning tool, but should not generally be considered deterministic as the final decision on eligibility for the National Register results from the processes governed by the applicable historic preservation law.

Sometimes a design type is more abundant or rare in adjacent states.

Original, unaltered bridge rails are sometimes the most important character-defining feature of historic bridges since they are often the most easily visible bridge element. For steel and iron truss bridges, pin connections are a character-defining feature and rivets or riveted connections may be considered a character-defining feature.

The rarity of a surviving example of some design or detail can lend historic significance to a bridge, but sometimes it is not feasible to retain these features while providing an acceptable degree of safety, i.e. a non-redundant pin-and-hanger support.

1.3.4—Project Alternatives

A range of alternatives should be considered for any project adversely affecting a historic bridge. Commonly considered alternatives include rehabilitation, relocation, restricting traffic, constructing a parallel structure, and conversion to pedestrian use. If a historic bridge can be used as-is or with rehabilitation to satisfy the intended level of service, that would typically be the preferred alternative. The choice of preferred alternative should also take into account the effects to other cultural and environmental resources in the area.

For rehabilitation, reconstruction, restoration, or preservation of a historic bridge, *The Secretary of the Interior's Standards* apply and provide additional guidance on sustainability for these projects.

The following types of changes are examples of actions that may meet *The Secretary of the Interior's Standards*:

- Selected reversible changes such as guide rails;
- Addition of post-tensioning in a non-obtrusive manner;
- Vertical clearance improvement when the increase is proportional;
- Reversible changes that “harden” the bridge for extraordinary events or degradation, such as suspension bridge cable protective systems or adding plates to built-up members; or
- In-kind replacement of members using similar shapes and dimensions.

1.3.5—Limit States

1.3.5.1—Strength Limit State

Design historic bridge preservation and rehabilitation projects using load and resistance factors consistent with the intended level of service.

When allowed under state requirements, it is acceptable to design historic bridge preservation and rehabilitation projects using the *AASHTO Standard Specifications for Highway Bridges*.

C1.3.4

Some agencies have had good experience relocating truss bridges that cannot satisfy the intended level of service in the bridges' original locations.

The need for good relations between the Owner and the SHPO/THPO cannot be overstated. The Section 4(f) and Section 106 processes function more smoothly if the SHPO/THPO is in favor of the proposed actions. For example, there are sometimes minor alterations that greatly help in meeting the functionality needs of the bridge, which can be considered “*de minimis*” or “no adverse effect”.

Technology offers interesting and effective ways to improve communication with the SHPO/THPO and stakeholders. 3D renderings of proposed aesthetic changes are useful, as are 3D printed models of elements such as bridge rails. It is good practice to discuss feasible design alternatives with the SHPO/THPO.

See *DRAFT Secretary of Interior's Standards for Bridges in Pennsylvania* for more information on the application of these standards.

C1.3.5.1

The intended level of service determines what design loading is appropriate, based on the context of the historic bridge and its use, e.g. a highway bridge repurposed into bicycle/pedestrian service would need the capacity to carry bicycle and pedestrian design live loading rather than full HL-93 live load.

When ownership of a historic bridge is transferred to other entities and there is a change in the intended level of service, the new owner should be notified of the appropriate design loading and corresponding intended level of service. Consider providing a historic bridge management plan that outlines the new intended level of service.

1.3.5.2—Service Limit State

Design historic bridge preservation and rehabilitation projects for deformations, stress levels, and crack widths consistent with the intended level of service. Consider the effect of changes in code requirements, material properties, and detailing practices on these deformations, stress levels, and crack widths.

1.3.5.3—Fatigue and Fracture Limit State

Design historic bridge preservation and rehabilitation projects using load and resistance factors and probabilities of detection consistent with the intended level of service.

1.3.6—Ductility

Incorporate ductile materials and details to the highest extent practicable, recognizing that structural performance may be limited by the ductility of existing components.

1.3.7—Redundancy

Provide internal redundancy to the greatest extent practicable, consistent with the intended level of service.

C1.3.7

Improvements in internal redundancy can be used to improve structural safety and serviceability. See *AASHTO Guide Specifications for Analysis and Identification of Fracture Critical Members and System Redundant Members*; *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-Up Steel Members*; *FHWA Steel Bridge Design Handbook, Redundancy*, Publication No. FHWA-HIF-16-002-Vol. 9; *FHWA Clarification of Requirements for Fracture Critical Members, Memorandum HIBT-10*; and *NCHRP Report 406, Redundancy in Highway Bridge Superstructures* for further information.

1.3.8—Functional Features

Design historic bridge preservation and rehabilitation projects to provide the following features appropriate for the intended level of service:

- Vertical clearance for traffic;
- Vertical clearance for navigation;
- Horizontal clearance for traffic;
- Horizontal clearance for navigation;
- Design high water level;
- Re-directive (crash mitigating) properties of bridge rail;
- Strength of bridge rail;
- Accessibility accommodation;
- Treatment of rutted pavements; and
- Utility accommodation.

1.3.9—Corrosion Protection

Extend service life by employing corrosion protection appropriate for the intended level of service and historic preservation needs.

1.3.10—Route Location

Verify that the bridge location is adequate for the intended level of service. Consider the suitability of the existing location in terms of:

- Historic preservation needs;
- Economic values;
- Social and environmental concerns;
- Costs of maintenance and inspection; and
- Intended level of traffic service and safety.

C1.3.8

When ownership of a historic bridge is transferred to other entities and there is a change in the intended level of service, the new owner should be notified of the limitations of functional features and the corresponding intended level of service.

C1.3.9

Corrosion protection systems include coating systems on structural steel bridges, impressed-current cathodic protection systems on reinforced concrete bridges, use of passive anodes in concrete repairs and patches, concrete sealers, low-permeability deck overlays, and waterproofing membranes. Corrosion protection systems for steel substructures submerged in water include the use of bulk anodes attached to steel pilings and tar-based coatings.

C1.3.10

Historic bridge preservation and rehabilitation projects typically do not include changes to bridge location. They do, however, need to address the suitability of the bridge in its location for the intended level of service.

1.3.11—Intended Level of Service

The intended level of service is the degree of structural capacity and functionality a preservation project is designed to provide.

Select the intended level of service according to the actual usage and functional category of the roadway and pedestrian path, consistent with the Owner's classification of the bridge for emergency response vehicles, security, defense, economic, or safety purposes.

1.3.12—Service Life Design

Perform service life design according to the AASHTO *Guide Specifications for Service Life Design of Highway Bridges*. Design foundations, substructures, and main structural members in historic bridge preservation and rehabilitation projects to provide enhanced or maximum service life, depending on the level of historic significance. Design renewable components such as expansion joint seals, bearings, drainage systems, wearing surfaces, barriers, access components, and railings for appropriate replacement cycles.

1.3.13—Economics

An organized bridge preservation program can be used to cost-effectively maintain historic bridges in “Fair” or “Good” condition. Such a program relies on the principle that timely preservation actions can prevent or delay costly future repairs.

For more information on bridge preservation programs and conditions, see the FHWA *Bridge Preservation Guide*.

C1.3.11

The intended level of service should be consistent with actual use of the structure and functional category of the roadway and pedestrian path.

C1.3.12

Numerical design life goals are not particularly meaningful for historic bridge preservation and rehabilitation projects. In practice, these projects should leave the bridge in condition to serve with reasonable maintenance indefinitely into the future. See the AASHTO *Maintenance Manual for Roadways and Bridges* for further information on routine maintenance.

C1.3.13

Historic bridge preservation and rehabilitation projects can produce cost savings when these projects are compared with bridge replacement, especially when replacement cost includes avoidance of environmental impacts and mitigation of traffic and community impacts.

In one example, a 570-ft concrete box girder bridge with heavy chloride contamination and concrete damage was rehabilitated and treated with ICCP at a cost of \$3.6M, when replacement had been programmed at \$30M. The site included endangered plants at both ends of the bridge, and bridge replacement would have required a diversion bridge or a long-term bridge closure.

In another example, a 104-ft reinforced concrete deck girder bridge with extensive spalled concrete was rehabilitated and treated with zinc anodes at a cost of \$0.5M, when replacement had been programmed for \$9.7M.

1.4—REFERENCES

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SECTION 2: GENERAL DESIGN AND LOCATION FEATURES

2.1—SCOPE

This Section provides strategies for historic bridge preservation and rehabilitation projects to address:

- clearances,
- environmental protection,
- accessibility,
- aesthetics,
- geological issues,
- economy,
- rideability,
- durability,
- constructability,
- inspectability,
- maintainability,
- hydrology and hydraulics, and
- traffic safety.

Strategies for drainage facilities and protection against water, ice, and salt exposure are included.

C2.1

This Section is intended to provide the Designer with sufficient information to determine the scope of historic bridge preservation and rehabilitation projects.

2.2—DEFINITIONS

ADT—Average Daily Traffic.

ASR—Alkali–Silica Reaction, a form of alkali–aggregate reaction in which components of concrete aggregate attack the cement paste, creating an expansive gel that causes cracking.

Design Exception or Deviation—Documentation of features that do not meet governing design standards, but that are deemed acceptable for a specific situation.

Geohazards—Geological conditions with potential to damage structures, such as faults, landslides, and rock-falls.

GPS—Global Positioning System, a satellite-based radionavigation system.

Intended Level of Service—The degree of structural capacity and functionality a preservation project is designed to provide.

Lidar—Three-dimensional radar-based scanning technology that produces point clouds representing the scanned object.

Life Safety Performance Level Seismic Retrofit—Seismic retrofit where the goal is to prevent collapse and loss of life, but may leave the bridge unserviceable after the seismic event.

Operational Performance Level Seismic Retrofit—Seismic retrofit where the goal is to keep the bridge functional after the seismic event.

PL2—Operational performance level of seismic retrofit enabling full service for emergency vehicles and minimal, repairable damage.

PL3—Fully Operational performance level of seismic retrofit enabling full service for all vehicles and negligible damage.

SHPO—State Historic Preservation Officer.

SSPC—The Society for Protective Coatings, formerly known as the Steel Structures Painting Council.

THPO—Tribal Historic Preservation Officer.

2.3—DESIGN EXCEPTIONS

When features do not satisfy AASHTO and state design standards, but are acceptable for the intended level of service, document these exceptions to the standards using the applicable state design exception or deviation process.

C2.3

Typically, states have design exception or deviation processes that document the features that do not satisfy the governing standards; rationale for accepting these features; and an approval process.

Appropriate design exceptions or deviations are important elements of many historic bridge preservation projects.

2.4—ADEQUACY OF LOCATION FEATURES

2.4.1—General

Provide features consistent with the intended level of service. Justify and document features that do not conform to state requirements and AASHTO standards.

C2.4.1

A design exception may be required for features that do not fully comply with applicable requirements.

2.4.2—Bridge Site Arrangement

2.4.2.1—Traffic Needs

Verify that the existing bridge location and roadway alignment satisfies traffic needs, consistent with the intended level of service.

C2.4.2.1

Traffic needs may include traffic on the bridge and traffic below the bridge, and may include vehicles, railroads, navigable waterways, bicycles, and pedestrians. Additional considerations may include land use policy in the area, Endangered Species Act compliance, and special uses of adjacent land such as conservation easements or wildlife refuges.

2.4.2.2—Traffic Safety

2.4.2.2.1—Protection of Structures

Consider the need for protective devices to protect the bridge from traffic exceeding the intended level of service.

C2.4.2.2.1

Covered bridges and through trusses especially can benefit from protective devices that help exclude inappropriate traffic. If the historic bridge exists on a route that could be recommended as a detour by commercial routing software, consider that over-dimension or overweight loads may attempt to use the structure.

2.4.2.2.2—Protection of Users

Provide bridge railings that conform to the requirements of Section 13 on railings.

Provide movable bridge traffic control devices that conform to the requirements for Traffic Control at Movable Bridges in the *Manual on Uniform Traffic Control Devices* (MUTCD).

2.4.2.2.3—Geometric Standards

Design exceptions may be required to justify and document geometric features that do not satisfy state requirements and *A Policy on Geometric Design of Highways and Streets* (the AASHTO Green Book), but which are consistent with the intended level of service. For low-volume facilities, the AASHTO *Guidelines for Geometric Design of Low-Volume Roads* may be applicable as an alternative.

2.4.2.2.4—Road Surfaces

Design exceptions may be required to justify and document antiskid characteristics, crown, drainage, and superelevation that do not conform to state requirements and the AASHTO Green Book but which are consistent with the intended level of service. For low-volume facilities, the AASHTO *Guidelines for Geometric Design of Low-Volume Roads* may be applicable as an alternative.

2.4.2.2.5—Vessel Collisions

Verify the need for and condition of pier protection.

2.4.2.3—Survey

Survey needs will vary depending on the availability, quality, and accuracy of as-built drawings and existing survey records, and the type and limits of historic bridge preservation work.

Protective devices may include bollards, pavement markings, rumble strips, increased signage, or over-height vehicle protective systems.

C2.4.2.2.2

Consider rehabilitating original stop signals or signs to fulfill or augment MUTCD requirements on historic movable bridges.

C2.4.2.2.3

Geometric features include lane widths, shoulder widths, vertical curvature, horizontal curvature, vertical clearance, horizontal clearance, grade, sight distance, design speed, number of lanes, crown, and superelevation.

C2.4.2.3

Lidar point clouds offer an alternative to survey that in some cases may provide more detailed locational data for bridge features at lower cost than conventional survey. For dangerous sites, a Lidar point cloud may also significantly reduce the risk to surveyors.

Lidar point clouds have been used to document the current state of a covered bridge as mitigation for the adverse effect of a project. See USDA's *Use of Laser Scanning Technology to Obtain As-Built Records of Historic Covered Bridges* for more information.

Lidar point clouds can be used to create as-built plans of bridges with missing or incomplete original construction plans.

Lidar point clouds have also been used to determine dimensions for load rating analysis.

2.4.3—Clearances

2.4.3.1—Navigational

For bridges over navigable waterways, obtain permits for temporary encroachment into the navigational clearances, both horizontal and vertical, from the U.S. Coast Guard.

C2.4.3.1

Where applicable, early coordination with the Coast Guard is essential for the success of historic bridge preservation and rehabilitation projects.

Long-term changes to navigational clearances are uncommon in historic bridge preservation and rehabilitation projects.

Refer to *Code of Federal Regulations, 23 CFR, Part 650, Subpart H Navigational Clearances for Bridges; 33 U.S.C. § 401 Construction of Bridges, Causeways, Dams or Dikes Generally; Exemptions; and 33 U.S.C. § 491 through 535i Bridges Over Navigable Waters* for additional information.

2.4.3.2—Highway Vertical

Provide vertical clearance consistent with the intended level of service. A design exception may be required to justify and document any vertical clearances not in conformance with state requirements and the AASHTO Green Book. For low-volume facilities, the AASHTO *Guidelines for Geometric Design of Low-Volume Roads* may be applicable as an alternative.

C2.4.3.2

For through-truss structures, it may be feasible to reconfigure sway braces and portal frame bracing. See Article 6.14 for further information.

2.4.3.3—Highway Horizontal

Provide horizontal clearance consistent with the intended level of service. A design exception may be required to justify and document any horizontal clearances not in conformance with state requirements and the AASHTO Green Book. For low-volume facilities, the AASHTO *Guidelines for Geometric Design of Low-Volume Roads* may be applicable as an alternative.

C2.4.3.3

For pony-truss structures, it is sometimes feasible to widen by replacing or splicing floor beams and replacing the deck.

For through-truss structures, there are examples of widening by moving the truss panels farther apart. The suitability of this technique is dependent on the amount of widening and the existing bracing configuration. In addition, there are examples of widening by adding additional lines of truss panels framed into the sides of the existing truss (e.g., the Huey P. Long Bridge in Louisiana). It is also possible in some cases to cantilever additional deck surface on the outside of the truss panels.

For deck arch bridges, it is sometimes feasible to widen by reconstructing the deck overhang, sidewalk, and bridge rail. For filled spandrel arches, it is sometimes feasible to widen by reconstructing one or both spandrel walls and extending the arch barrel.

2.4.3.4—Railroad Crossing

Railroads typically own their right of way. When a project affects a railroad, they may make demands such as increased vertical or horizontal clearance. Their property rights typically allow them to prevent any work within their right of way until their requirements are met.

2.4.4—Environment

Containment of work-generated debris is required for bridge preservation work that generates dust or hazardous materials. Follow state and federal requirements for handling of hazardous materials.

Protect cultural sites (i.e., archaeological or historical) by appropriate measures that may include no-excavation zones, durable ground covers, and non-disclosure of information.

C2.4.3.4

Bridge preservation or rehabilitation can be designed to minimize construction impacts on the railroad.

Railroad permits can be very time-consuming to obtain. Railroad requirements for protection of rail traffic can be costly.

C2.4.4

SSPC Guide 6 provides guidance for containment of dust, debris, wet surface preparation wastes, hydro-demolition wastes, and other wastes.

Historic bridge preservation and rehabilitation projects can reduce or eliminate construction impacts on local communities; cultural sites; wetlands; and other aesthetically, environmentally, and ecologically sensitive areas as compared with bridge replacement. This can be an advantage when seeking permits.

In one example, a 130-foot through truss in a highly constrained urban site with poor detour options was rehabilitated and repainted with two nights of full closure and a long-term single lane closure. Bridge closure would have cut off each half of the town from the other for an extended period, and any expansion beyond the footprint of the existing bridge would have triggered difficult right-of-way choices (the town's grocery store or an apartment building and a community space).

In another example, a 100-foot reinforced concrete deck girder bridge five lanes wide in a high-traffic urban site with minimal detour options is being rehabilitated and treated with ICCP with no full closure and minimal lane closures. Local tourism businesses, the adjacent parks, and local residents all will benefit from the reduced construction impacts.

In each of these examples, the communities were subjected to far fewer impacts in terms of both traffic and lost business, difficult right-of-way decisions became unnecessary, and there were significant cost savings that allowed the Owner Agency to address other bridge needs elsewhere.

2.5—FOUNDATION INVESTIGATION

2.5.1—Office Studies

Study the topography of the bridge site to determine if there is evidence of geohazards from historical records, existing plans, pile record books, and in other records relating to nearby structures.

Office studies may include determination of foundation size and depth for stability and scour analysis, and should consider local and global failure mechanisms.

2.5.2—Field Investigation

Physically verify details from the plans and office studies to ensure the details and assumptions are valid.

Field investigation may include determination of foundation size and depth for stability and scour analysis.

For “Operational” PL2 or PL3 performance level seismic retrofits, conduct a subsurface investigation including borings and soil tests according to Article 10.4, to obtain design information.

2.6—DESIGN OBJECTIVES

2.6.1—Safety

Provide for the safety of the public. If allowed under applicable historic preservation laws, consider safety measures for maintenance, such as ladders, access platforms, fall arrest systems, and lighting. If allowed under applicable historic preservation laws, consider public safety measures such as pedestrian lighting.

2.6.2—Serviceability

2.6.2.1—Durability

Protect structural steel and iron components according to Article 6.8.

Protect reinforced concrete components according to Article 5.5.

Protect aluminum components according to Article 7.4.

Protect timber components according to Article 8.5.

C2.5.1

Lidar can be used to survey sites that are difficult or dangerous to access, such as in-water piers or rock escarpments.

Geologic hazards may include faults, landslides, and rockfalls.

C2.5.2

See the *Manual for Bridge Evaluation* for further information.

See the *Seismic Retrofitting Manual for Highway Structures: Part 1—Bridges*; AASHTO LRFD; and the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* for further information on seismic retrofits.

2.6.2.2—Inspectability

Consider the ability of bridge preservation and rehabilitation work to be inspected in the future.

Do not create hidden details that are difficult to inspect. When painting historic bridges, there are often areas that cannot be accessed. Provide access holes to allow surface preparation and coating of inaccessible areas. Specify removal of bolted-on cover plates when painting historic bridges, otherwise these areas will be contractually treated as inaccessible.

2.6.2.3—Maintainability

Consider the ability of bridge preservation and rehabilitation work to be maintained in the future.

2.6.2.4—Rideability

Ensure that expansion joint retrofits are set at proper elevations and deck overlays are finished appropriately.

2.6.2.5—Utilities

Work with utility owners to improve utility installations that hinder bridge preservation work or which are inappropriately attached to the structure.

2.6.3—Constructability

Historic bridge preservation sometimes relies on innovative means and methods to enable work that would not be feasible with ordinary means and methods, and often relies on extensive temporary works. The following information is not unique to historic bridge preservation, but is emphasized due to the importance of innovative means and methods and temporary works for the success of preservation projects.

C2.6.2.2

For example, end floor beams in steel structures have been altered to provide 6- to 8-in. diameter holes at 24- to 48-in. center-to-center spacing for preparation and coating access.

C2.6.2.3

Examples of addressing access needs for future maintenance include providing level surfaces near bearings for jacking and creating access openings with doors or covers in concrete box girder bridges.

If applicable, locate electrical control cabinets for cathodic protection systems, ice control systems, and structural health monitoring systems in safe locations that are convenient for routine maintenance and minimize aesthetic impact.

C2.6.2.5

For painted steel bridges, existing makeshift utility attachments often create difficulties, either by blocking access for effective surface preparation and coating application or by rubbing through the new coating system. Eliminate makeshift utility attachments and replace them with approved hardware.

For concrete bridges with cathodic protection, do not allow utility attachments to short-circuit the zinc coating to the steel reinforcement.

C2.6.3

Ordinarily, engineers are discouraged from specifying means and methods that a contractor would use to perform the work, as that limits the contractor's alternatives and therefore may increase cost. When specific innovative means and methods are necessary for the success of historic bridge preservation work, consider specifying the necessary innovative means and methods.

When specifying new or unusual methods of performing bridge preservation work, use appropriate demonstrations to verify that these methods are viable. When the new or unusual methods are essential to the success of the bridge preservation work, these methods must be explicitly specified. If the contracting community is not familiar with the new or unusual methods, provide demonstrations and known subcontractor contacts in a pre-bid meeting. Provide a possible construction sequence or construction sequence animation of the proposed work if appropriate.

Specify temporary works such as shoring or temporary work access and containments that are appropriate for the bridge preservation work. For loading of the existing structure by the temporary works, specify an allowable loading scenario that the bridge can safely support and require the contractor to provide bridge structural calculations if the allowable loading scenario is exceeded.

2.6.4—Economy

Historic bridge preservation sometimes relies on innovative means and methods that have little or no cost history, and often relies on costly temporary works. The following information is not unique to historic bridge preservation, but is emphasized due to the importance of innovative means and methods and temporary works for the success of preservation projects.

Make the project easy to bid by clearly defining the scope of work and clearly relating all work to specific bid items.

2.6.5—Bridge Aesthetics

In addition to the typical bridge aesthetic considerations, consider what modifications are acceptable under applicable historic preservation laws. Usually, this means making minimal changes to the appearance of the bridge.

New or unusual methods can expose contractors to a higher level of risk, especially if the new methods are contrary to common practice. Consider this effect when estimating the cost of bridge preservation work.

Performance specifications (i.e., outcome-based rather than prescriptive) are typically appropriate for bridge temporary works. Specifying means and methods is not recommended. See the *AASHTO Guide Design Specifications for Bridge Temporary Works* for further information.

Protect the structure by analyzing it for added loads that are selected to envelope reasonable temporary works alternatives, and specifying safe limits for the loading of the existing structure by the temporary works. In some cases a full refined analysis is required, while in many cases a simpler analysis is feasible to allocate excess load capacity identified in an existing load rating or gained by a lane closure or permit restriction. Contractors are typically not structural engineers and don't have enough information about the structure to analyze it for the temporary works loading, and specifications that only say "do not overstress the bridge" are difficult to enforce and to defend in court.

C2.6.4

Poorly defined scopes and bid items increase risk and may expose the bridge owner to cost increases without a corresponding increase in value.

C2.6.5

The importance of a good working relationship with the SHPO/THPO and stakeholders cannot be overstated.

3D renderings and 3D printed models help the SHPO/THPO and stakeholders make an informed decision with confidence. Similarly, alternative designs

sympathetic to the historic appearance of the bridge can help the SHPO/THPO and stakeholders successfully complete the Section 4(f) process or the Section 106 process.

2.7—HYDROLOGY AND HYDRAULICS

2.7.1—Temporary Works

Temporary works within the floodway should be designed consistently with the intended service period and the flood hazard created by the temporary structure.

2.7.2—Site Data

When reviewing the hydraulic capacity of an existing bridge, consider historical information on the performance of the structure during past floods, including observed scour, bank erosion, and structural damage due to debris or ice flows.

2.7.3—Scour

Provide appropriate scour countermeasures for bridges determined to be scour-critical.

C2.7.3

A scour-critical determination should include consideration of available historical data and known performance of the foundation over significant time. Note that an unknown foundation is automatically considered scour-critical.

Appropriate scour countermeasures may include monitoring in lieu of repairs, especially in cases where the bridge is considered scour critical but has a long history of operation without observable scour issues. Monitoring could include annual examinations and special inspections after major hydrologic events.

Scour is the predominant cause of bridge failure in the United States. For additional information on scour evaluation and countermeasures, see FHWA publications *Evaluating Scour at Bridges* and *Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance*.

2.7.4—Roadway Drainage

2.7.4.1—Type, Size, and Number of Drains

Consider deck drain improvement or elimination, or intercepting drainage before the bridge, in conjunction with bridge preservation and rehabilitation work.

C2.7.4.1

Deck drains on historic bridges tend to be small, prone to plugging with debris, and hard to clean. These problems can be eliminated by retrofitting with larger drains, avoiding bends tighter than 45 degrees, and adding cleanout fittings, as needed. Refer to FHWA's *Design of Deck Drainage* for further information on deck drain design.

2.7.4.2—Discharge from Deck Drains

Design deck drain retrofits to direct drainage away from bridge superstructure elements and substructure.

2.7.4.3—Drainage of Structures

Provide drain holes and other drainage provisions as appropriate when rehabilitating structures with substandard drainage.

2.8—BRIDGE SECURITY

For covered bridges, provide appropriate security measures to address their unique risks, i.e. arson, fire, and vandalism.

C2.8

Security measures used on covered bridges include camera systems, thermal imaging camera systems, smoke detectors, and sprinkler systems. Additional information on covered bridge security can be found in *USDA Report FPL-GTR-223 Covered Bridge Security*.

When planning for bridge security, suspension bridge anchorages, towers, main cables, and suspender cables are of particular concern, as are movable bridge control rooms or machinery rooms.

2.9—REFERENCES

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SECTION 3: LOADS AND LOAD FACTORS

3.1—SCOPE

This Section defines loads and load factors for evaluation and analysis of historic structures.

3.2—DEFINITIONS

Dead Loads (DC and DW)—Loading induced on a structure by gravity acting on the self-weight of the structure's components.

Dynamic Load Allowance (IM)—Loading induced on a structure by dynamic effects acting on the self-weight of loaded vehicles, i.e. impact effects.

Earth Pressure Loads (EH, ES, LS, and DD)—Loading induced on a structure by adjacent soils, i.e. the force reacted by the structure to hold adjacent soils in place.

Earthquake Effects (EQ)—Loading induced on a structure by the ground motions produced by an earthquake.

Gravity Loads (LL and PL)—Loading induced on a structure by gravity acting on the self-weight of loaded vehicles, bicycles, and pedestrians.

Kinematic Earth Pressure Effects—Changes in earth pressure due to seismic motion.

Life Safety Performance Level Seismic Retrofit—Seismic retrofit where the goal is to prevent collapse and loss of life, but may leave the bridge unserviceable after the seismic event.

Operational Performance Level Seismic Retrofit—Seismic retrofit where the goal is to keep the bridge functional after the seismic event.

Temporary Works—Temporary structures and components built to enable permanent construction and removed when no longer needed. Examples include formwork for concrete, work platforms, scaffolding, containment structures, temporary retaining walls, and shoring.

Wind Loads (WL and WS)—Loading induced on a structure by the action of wind.

3.3—ABBREVIATIONS

DC—Dead load of structural components and nonstructural attachments.

DD—Downdrag force.

DW—Dead load of wearing surfaces and utilities.

EH—Horizontal earth pressure load.

ES—Earth surcharge load.

EQ—Earthquake load.

IM—Vehicular dynamic load allowance.

LL—Vehicular live load.

LS—Live load surcharge.

PL—Pedestrian live load.

PL2—Operational performance level of seismic retrofit enabling full service for emergency vehicles and minimal, repairable damage.

PL3—Fully Operational performance level of seismic retrofit enabling full service for all vehicles and negligible damage.

WL—Wind on live load.

WS—Wind load on structure.

3.4—LOAD FACTORS AND COMBINATIONS

3.4.1—Load Factors and Load Combinations

When analyzing an existing structure, use the load factors defined in Table 6A.4.2.2-1 of the *AASHTO Manual for Bridge Evaluation* (AASHTO MBE), as modified by state requirements, and use the load combinations defined in AASHTO LRFD.

C3.4.1

A design exception may be required if a project is designed with load and resistance factors less conservative than those required by AASHTO LRFD.

State requirements may allow analysis according to the *AASHTO Standard Specifications for Highway Bridges*.

3.4.2—Load Factors for Construction Loads Applied to Existing Structures

C3.4.2

When a project includes construction loads such as a suspended work platform or supplies and equipment placed on the bridge, analyze the existing structure for these construction loads.

When analyzing an existing structure for construction loads, use the load factors defined in Table 6A.4.2.2-1 of the AASHTO MBE, as modified by state requirements. Use operating load factors when the Strength I limit state applies. For the construction loads, use the same load factor as is specified for the simultaneously applied live load. Use the load combinations defined in AASHTO LRFD including all applicable load effects.

Construction loads increase the stress in many bridge components. The structural capacity of the bridge to support suspended work platforms may be provided from excess capacity identified by analysis, or by closing a lane on the bridge to reduce live load. The structural capacity of the bridge may also be affected by wind loading on temporary works, especially on containment structures which significantly increase the projected area for wind to act upon.

Determine the applicable limit state, i.e. Strength I or Strength II, consistent with the intended level of service and state requirements.

Temporary loads during bridge relocations must also be analyzed to avoid unanticipated load reversals in truss members.

Occasionally a bridge will require some structural repairs to be completed before the temporary works can be fully installed. In these cases, it is important to specify the required timing of work elements.

Additional information on loads and load factors applicable during construction is provided in ASCE 37 *Design Loads on Structures During Construction*.

3.5—LIVE LOADS

3.5.1—Gravity Loads: LL and PL

3.5.1.1—Number of Design Lanes

Determine the number of lanes for analysis according to AASHTO MBE Article 6A.2.3.2 and state requirements.

C3.5.1.1

State requirements may allow analysis according to the AASHTO *Standard Specifications for Highway Bridges*.

3.5.1.2—Design Vehicular Live Load

Determine the applicable design live load consistent with the intended level of service, according to AASHTO MBE Article 6A.2.3.1 and state requirements. Depending on the intended level of service, the appropriate design live load for a historic bridge may be H10-44, H15-44, HS15-44, H20-44, or HS20-44 as detailed in the AASHTO *Standard Specifications for Highway Bridges*, in lieu of HL-93.

C3.5.1.2

Depending on the intended level of service, it may be appropriate to have a bridge in service with a load posting. Determine the applicable limit state, i.e. Strength I or Strength II, consistent with the intended level of service and state requirements.

AASHTO MBE provides a Load and Resistance Factor analysis approach, which can be used to analyze a bridge for alternate live loading. State requirements may allow analysis according to the AASHTO *Standard Specifications for Highway Bridges*.

3.5.1.3—Design Pedestrian Load

Determine the applicable pedestrian load consistent with the intended level of service, according to AASHTO LRFD Article 3.6.1.6, the AASHTO *LRFD Guide Specifications for the Design of Pedestrian Bridges*, and state requirements.

C3.5.1.3

The design pedestrian load may include bicycle, equestrian, and light maintenance vehicle traffic.

State requirements may allow analysis according to the AASHTO *Standard Specifications for Highway Bridges*.

3.5.2—Dynamic Load Allowance: IM

For Strength and Service limit states, except on deck joints and timber components, determine the impact factor for analysis according to AASHTO MBE Article 6A.4.4.3-1 as modified by state requirements.

C3.5.2

Reducing roadway speed may allow a reduction in impact factor.

State requirements may allow analysis according to the AASHTO *Standard Specifications for Highway Bridges*.

3.6—WIND LOAD: WL AND WS

Consider the effect of wind load on any temporary works or permanent components that are added or modified in ways that increase surface area or susceptibility to wind.

Design permanent components for wind loads according to the AASHTO *Guide Specifications for Wind Loads on Bridges During Construction*, and design temporary works for wind loads according to the AASHTO *Guide Specifications for Bridge Temporary Works*.

When relocating a structure, verify that the structure can withstand the wind loading at the new location.

3.7—EARTHQUAKE EFFECTS: EQ

Match seismic retrofit work scope to the intended level of service for the bridge.

Design seismic retrofits to minimize visual impact. Maintain proportions of structural members relative to other members and the bridge as a whole.

3.8—EARTH PRESSURE: EH, ES, LS, AND DD

Design operational performance level seismic retrofits according to the *AASHTO Guide Design Specifications for Bridge Temporary Works*, including kinematic earth pressure effects.

3.9—TEMPORARY WORKS

3.9.1—Load Factors

Design temporary works according to the *AASHTO Guide Design Specifications for Bridge Temporary Works* and the *AASHTO Guide Specifications for Wind Loads on Bridges During Construction*.

Design temporary works that support workers, i.e. scaffolding or work platforms, to comply with OSHA 1926.451(a)(1), 1926.451(a)(3), and 1926.451(a)(4).

3.9.2—Horizontal Wind Pressure

Temporary works may be designed for reduced wind pressures as appropriate for the duration of construction work and the intended level of service, according to the *AASHTO Guide Specifications for Wind Loads on Bridges During Construction*.

3.10—REFERENCES

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C3.7.1

Seismic design for bridge preservation and rehabilitation work typically involves life safety performance level seismic retrofits. When appropriate, based on the intended level of service, operational PL2 or PL3 performance level seismic retrofit is warranted. See FHWA-HRT-06-032 *Seismic Retrofitting Manual for Highway Structures: Part 1—Bridges*; AASHTO LRFD; and the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* for further information on seismic retrofits.

C3.9.1

Additional information on loads applicable during construction for complex and non-bridge structures is provided in *ASCE 37 Design Loads on Structures During Construction*.

OSHA 1926.451 requires suspension ropes and connecting hardware to have breaking strength greater than 6.0 times the maximum working load, and all other components to have breaking strength greater than 4.0 times the maximum working load.

C3.9.2

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